Quality Metrics 1998
Version 5

Estimated Impacts of OTT Programs

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Quality Metrics was developed as a way of measuring the expected long-term benefits of programs (on a technology basis) conducted in EE/RE. These benefits are to illustrate to Congress the betterment of society through the development more efficient/renewable technologies. Initially, these benefits included energy and petroleum reductions, CO_2 reductions, and the associated economic impacts on GDP and jobs.

The QM process has grown to include program performance measures and criteria pollutant reductions. Program performance measures detail the expected short-term program accomplishments.

OTT has expanded the concept of QM to include:

-national industry and consumer benefit cost analyses,

-and source versus up stream emissions.

Changes in Analysis

- Version 1:   Revised vehicle characterizations based on input from sector representatives.
- Version 2: Revised heavy truck vehicle characterizations and vehicle characterizations based on input from sector staff.
- Version 3: Revised consumer choice coefficients to latest national survey.
- Version 4: Light truck advanced diesel vehicles are included in the Heavy Vehicle R&D planning unit; Revised economic analysis
- Version 5: Incorporates all comments received since September 1996 including EE peer review.

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Planning units now reflect benefits by the four offices in OTT, where as in the past planning units reflected benefits by technology type. Estimates are still developed on a technology basis.

OTT has improved the analytical modeling process with the addition of the Size Class Sales (SCS) Model and the Economic Spreadsheet Model (ESM). The coefficients for the SCS model are estimated from a national survey conducted in 1995.

Planning unit assumptions are detailed by size/market class and technology type for both light and heavy duty vehicles.

The presentation will conclude with a discussion of the estimated impacts of OTT programs on energy use, emissions reductions, and economic growth.

Planning Units

- TECHNOLOGY UTILIZATION: CNG
- BIOFUELS: Ethanol
- ADVANCED AUTOMOTIVE TECHNOLOGIES:
  - Electric Vehicle R&D:
  - Fuel Cell R&D: Ethanol Reformer
  - Hybrid Vehicle R&D: 3X Efficiency, Gasoline
  - Light Duty Engine R&D: Advanced Diesel
- ADVANCED HEAVY VEHICLE TECHNOLOGIES:
  - Classes 7 & 8
  - Classes 3 - 6
  - Class 1 & 2 diesel trucks
- MATERIALS TECHNOLOGIES:
  - Propulsion System Materials
  - Light-duty Vehicle Materials
  - Heavy Vehicle Materials

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Technology Utilization includes the penetration of light duty CNG vehicles in the household market and alternatively fueled vehicles mandated by EPAct.
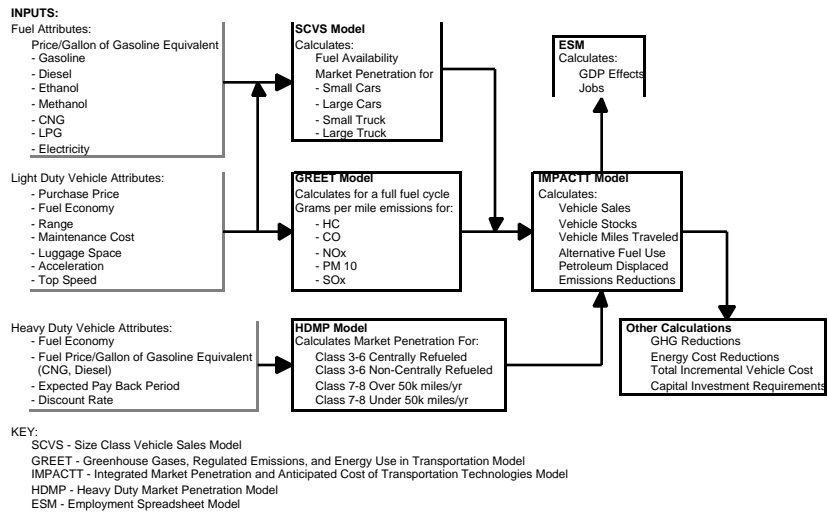
Biofuels includes ethanol fuel used by Flex-Fuel, Dedicated Alcohol, and Fuel Cell Vehicles.

Advanced Automotive Technologies includes impacts from the use of electric vehicles, hybrid vehicles, and advanced diesels in cars. Only the benefits attributed to the efficiency improvement of Fuel Cell vehicles is estimated for this planning unit.

Advanced Heavy Vehicle Technologies includes the expected benefits achieved through the introduction of alternative fuels and high efficiency heat engines in class 3 through 8 heavy vehicles. Also included are benefits estimated from the use of advanced diesels in light trucks.

Materials Technologies will include benefits from the introduction of lightweight materials in light and heavy vehicles. Benefits will also be calculated for the introduction of ceramic components in heat engines.

Modeling Process

INPUTS:

Fuel Attributes:
　Price/Gallon of Gasoline Equivalent
　- Gasoline
　- Diesel
　- Ethanol
　- Methanol
　- CNG
　- LPG
　- Electricity

Light Duty Vehicle Attributes:
　- Purchase Price
　- Fuel Economy
　- Range
　- Maintenance Cost
　- Luggage Space
　- Acceleration
　- Top Speed

Heavy Duty Vehicle Attributes:
　- Fuel Economy
　- Fuel Price/Gallon of Gasoline Equivalent
　　(CNG, Diesel)
　- Expected Pay Back Period
　- Discount Rate

SCVS Model
Calculates:
　Fuel Availability
　Market Penetration for
　- Small Cars
　- Large Cars
　- Small Truck
　- Large Truck

GREET Model
Calculates for a full fuel cycle
Grams per mile emissions for:
　- HC
　- CO
　- NOx
　- PM 10
　- SOx

HDMP Model
Calculates Market Penetration For:
　Class 3-6 Centrally Refueled
　Class 3-6 Non-Centrally Refueled
　Class 7-8 Over 50k miles/yr
　Class 7-8 Under 50k miles/yr

ESM
Calculates:
　GDP Effects
　Jobs

IMPACTT Model
Calculates:
　Vehicle Sales
　Vehicle Stocks
　Vehicle Miles Traveled
　Alternative Fuel Use
　Petroleum Displaced
　Emissions Reductions

Other Calculations
　GHG Reductions
　Energy Cost Reductions
　Total Incremental Vehicle Cost
　Capital Investment Requirements

KEY:
　SCVS - Size Class Vehicle Sales Model
　GREET - Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
　IMPACTT - Integrated Market Penetration and Anticipated Cost of Transportation Technologies Model
　HDMP - Heavy Duty Market Penetration Model
　ESM - Employment Spreadsheet Model

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This slide illustrates the flow of input and calculations through the modeling process.

Savings due from heavy vehicle materials and non-household fleets are calculated off-line.

Analytical Tools

- Household Size Class Sales (SCS) Model: John Maples, UT
- Offline Fleet Calculations: John Maples and Jim Moore
- Heavy Duty Market Penetration Model (HDMP): John Maples, UT; Jim Moore, ANL and; Vince Schaper, NREL
- Integrated Market Penetration and Anticipated Cost of Transportation Technologies (IMPACTT) Model: Marianne Mintz, ANL
- Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) Model: Michael Wang, ANL
- Economic Spreadsheet Model (ESM): Vince Schaper, NREL

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SEE ATTACHED

The SCS model was added this year to help identify the successful introduction of technologies by size class.

The HDMP model was expanded to estimate market penetration in four vehicle use categories.

Calculations of emissions were refined in the IMPACTT model.

GREET was used to identify tail pipe versus up-stream emissions.

The ESM was added this year to estimate the economic impacts of OTT programs.

SCS Model Structure

- Type: Demand-side discrete choice Logit model with Supply-side feedback loops
- Coefficients: Calibrated using 1995 National stated-preference database
- Four Vehicle Size Classes
  Small Car   Large Car
  Passenger Truck   Cargo Truck
- Feedback Loops
  Alternative fuel availability affected in year t by the demand for that fuel in year t-1.
- Technology S-curve Introduction

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This slide describes the basic structure and information requirements of the SCS model.

Small cars represent compact and sub-compact cars. Large cars represent mid-size and large cars. Passenger trucks represent those trucks that are primary designed and used as passenger carrying vehicles (mini vans, sport utilities). Cargo trucks represent trucks that are primary designed and used to carry cargo (pickups, large vans).

Initial market penetration is retarded by the technology S-curve introduction. The the length of the S-curve (years) is determined by the user and limits initial market penetration for the user specified amount of time.

SCS Model Inputs

- Vehicle Inputs
  - Vehicle Purchase Price   - Range
  - Fuel Economy   - Maintenance Cost
  - Acceleration   - Top Speed
  - Luggage Space

- Fuel Inputs
  - Price per gallon of gasoline equivalent (Btu)
  - Fuel Availability

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This slide illustrates the vehicle and fuel attribute inputs used to estimate light duty vehicle market penetration by size class.

Fuel availability is calculated endogenously. The user can constrain the growth in fuel availability for ethanol fuels.

Light Truck Classification

Small   Large

Pickup

CARGO

Van

PASSENGER

Sport Utility

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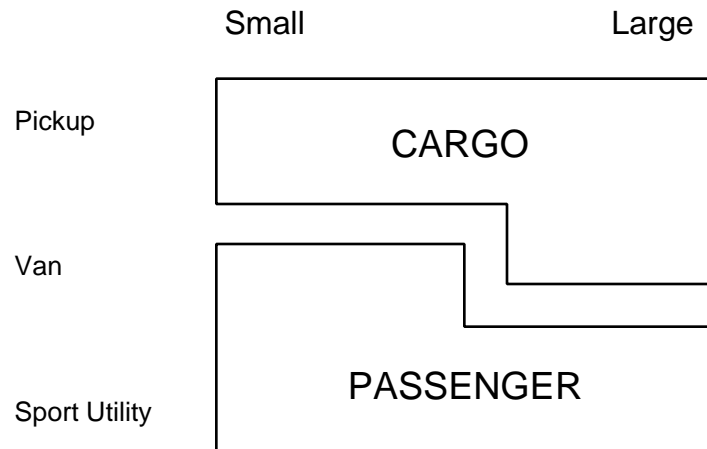
Technology Introduction

Technology	Small Car		Large Car		Sport Utility Mini Van		Large Truck Large Van	
	Intro	S-curve	Intro	S-curve	Intro	S-curve	Intro	S-curve
Advanced Diesel	2007	3	2007	3	2005	5	2005	5
Flex Alcohol	-	-	1998	3	1999	3	1999	3
Dedicated Alcohol	2005	5	2005	5	2005	5	2005	5
CNG Dedicated	-	-	1998	5	2002	3	1998	5
Electric	1998	5	-	-	1999	5	-	-
Hybrid	2008	3	2005	5	2011	3	-	-
Fuel Cell	-	-	2009	5	2013	3	-	-

Intro: Year technology is introduced into market
S-curve: Number of years before technology meets full market demand

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This slide illustrates which technologies are introduced into the different size classes and the years that they are introduced.

Notice: there are no flex-fuel or fuel cell vehicles in the small car class, there are no electric's in the large car class, and there are no electric's, hybrids, or fuel cells in the large truck class.

For this analysis, 3 and 5 year S-curve lengths were used. The 5 year lengths are representative of the first time the technology was introduced into the market. The 3 year lengths are representative of a more established technology as moves into other size classes.

The DOE Policy Office is conducting a study to model the transition to advanced transportation technologies and alternative fuels that will provide greater insight into technology introduction.

OTT has not considered LPG (propane) or methanol in its analysis for two reasons: (1) OTT conducts minimal R&D efforts with those fuels, and (2) recent DOE/Policy Office analysis indicates that these fuels would be imported in large amounts if they were used on a large scale in the transportation sector.

Technology Characteristics Large Car

TECHNOLOGY	YEAR OF INTRO.	YEAR OF MATURITY	VEHICLE COST RATIO	FUEL ECONOMY RATIO	RELATIVE RANGE	TRUNK SPACE	ACCEL (0-60), SEC.	TOP SPEED, MPH
CONV.	NA	NA	$22,000	21.9 MPG	350 MILES	18.9 CU. FT.	11.0 s.	125 MPH
ADVANCED DIESEL	2007	2012	Intro: 1.1 Mat.: 1.05	Intro: 1.3 Mat.: 1.3	Intro: 1.2 Mat.: 1.2	Intro: 1.0 Mat.: 1.0	11.0 s.	100 mph
HYBRID VEHICLE	2005	2010	Intro: 1.3 Mat: 1.1	Intro: 1.5 Mat: 1.75	Intro: 1.0 Mat: 1.0	Intro: 0.95 Mat: 0.95	12.0 s.	90 mph
FUEL CELL VEHICLE	2009	2013	Intro: 1.4 Mat.: 1.2	Intro: 2.5 Mat.: 2.5	Intro: 1.0 Mat.: 1.2	Intro: 0.8 Mat.: 0.8	12.0 s.	80 mph
NATURAL GAS VEHICLE	1998	2002	Intro: 1.2 Mat.: 1.07	Intro: 1.0 Mat.: 1.0	Intro: 0.66 Mat.: 0.75	Intro: 0.75 Mat.: 0.75	11.0 s.	125 mph
DEDICATED ALCOHOL	2005	2005	Intro: 1.0 Mat.: 1.0	Intro: 1.08 Mat.: 1.08	Intro: 0.9 Mat.: 0.9	Intro: 1.0 Mat.: 1.0	11.0 s.	125 mph

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Technical Characteristics for Large Cars (e.g. mid-size and larger) are shown on this chart. In 1995, large cars accounted for 27.5% of sales. Average characteristics include (1) 208 cubic inch engines; (2) 163.6 HP; and (3) 108.5 inch WHEELBASE. Davis, Stacy, Transportation Energy Data Book: Edition 16, Oak Ridge National Laboratory, ORNL-6898, July 1996.

Some values for potential review include the following:

- Fuel cell vehicle cost: 40% greater than ICE

- Ethanol vehicle fuel economy 8% greater than ICE

- NGV range: 75% of ICE

Note that acceleration ratings reflect 0 to 60 MPH performance.

Technology Characteristics Small Car

TECHNOLOGY	YEAR OF INTRO.	YEAR OF MATURITY	VEHICLE COST RATIO	FUEL ECONOMY RATIO	RELATIVE RANGE	TRUNK SPACE	ACCEL (0-60), SEC.	TOP SPEED, MPH
CONV.	NA	NA	$16,000	30.8 MPG	350 MILES	12.9 CU. FT.	11.9 s.	117 MPH
ADVANCED DIESEL	2007	2010	Intro: 1.1 Mat.: 1.05	Intro: 1.2 Mat.: 1.25	Intro: 1.2 Mat.: 1.2	Intro: 1.0 Mat.: 1.0	12.9 s.	100 mph
HYBRID VEHICLE	2008	2015	Intro: 1.3 Mat: 1.2	Intro: 1.9 Mat: 2.3	Intro: 1.0 Mat: 1.0	Intro: 1.0 Mat: 1.0	12.9 s.	90 mph
ELECTRIC VEHICLE	1998	2015	Intro: 2.2 Mat.: 1.15	Intro: 3.0 Mat.: 3.0	Intro: 0.3 Mat.: 0.57	Intro: 0.5 Mat.: 0.7	14.0 s.	80 mph
DEDICATED ALCOHOL	2005	2005	Intro: 1.0 Mat.: 1.0	Intro: 1.08 Mat.: 1.08	Intro: 1.0 Mat.: 1.0	Intro: 1.0 Mat.: 1.0	11.9 s.	117 mph

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Technical Characteristics for Small Cars (e.g. compact and smaller) are shown on this chart.   In 1995, small cars accounted for 32.1% of sales. Average characteristics include (1) 138 cubic inch engines; (2) 122.6 HP; and (3) 101.8 inch wheelbase. Davis, Stacy, Transportation Energy Data Book: Edition 16, Oak Ridge National Laboratory, ORNL-6898, July 1996.

Some values that caught our attention as candidates for potential review include the following:

- Electric vehicle cost: 2.2 times greater than ICE

- Fuel cell vehicle fuel economy 1.9 times greater than ICE

Acceleration ratings reflect 0 to 60 MPH performance.

Technology Characteristics Passenger Truck

TECHNOLOGY	YEAR OF INTRO.	YEAR OF MATURITY	VEHICLE COST RATIO	FUEL ECONOMY RATIO	RELATIVE RANGE	TRUNK SPACE	ACCEL (0-60), SEC.	TOP SPEED, MPH
CONV.	NA	NA	$20,500	21.9 MPG	350 MILES	NA	12.0 s.	121 MPH
ADVANCED DIESEL	2003	2008	Intro: 1.15 Mat.: 1.1	Intro: 1.15 Mat.: 1.25	Intro: 1.2 Mat.: 1.2	Intro: 1.0 Mat.: 1.0	13.0 s.	120 mph
ELECTRIC VEHICLE	1999	2015	Intro: 2.0 Mat: 1.15	Intro: 3.0 Mat: 3.0	Intro: 0.4 Mat: 0.6	Intro: 1.0 Mat: 1.0	14.0 s.	80 mph
HYBRID VEHICLE	2011	2015	Intro: 1.25 Mat: 1.2	Intro: 1.4 Mat: 2.1	Intro: 1.0 Mat: 1.0	Intro: 1.0 Mat: 1.0	13.0 s.	90 mph
FUEL CELL VEHICLE	2013	2013	Intro: 1.3 Mat.: 1.3	Intro: 2.5 Mat.: 2.5	Intro: 1.0 Mat.: 1.0	Intro: 0.8 Mat.: 0.8	13.0 s.	80 mph
NATURAL GAS VEHICLE	2002	2002	Intro: 1.1 Mat.: 1.1	Intro: 1.0 Mat.: 1.0	Intro: 0.75 Mat.: 0.75	Intro: 0.75 Mat.: 0.75	12.0 s.	121 mph
DEDICATED ALCOHOL	2005	2005	Intro: 1.0 Mat.: 1.0	Intro: 1.08 Mat.: 1.08	Intro: 0.9 Mat.: 0.9	Intro: 1.0 Mat.: 1.0	12.0 s.	1215 mph

These are the Vehicle Attribute Values for the Passenger Truck Category. In 1995, passenger trucks accounted for 21% of sales. Average characteristics include (1) 215 cubic inch engines; (2) 157.7 HP; and (3) 108.3inch wheelbase. Davis, Stacy, Transportation Energy Data Book: Edition 16, Oak Ridge National Laboratory, ORNL-6898, July 1996.

Passenger Trucks include sport utility vehicles and mini-vans.

Years of introduction have been reviewed for consistency among the four categories.

Note that we are showing both hybrid and electric vehicle technology as competing in this market segment.

Technology Characteristics
Cargo Truck

TECHNOLOGY	YEAR OF INTRO.	YEAR OF MATURITY	VEHICLE COST RATIO	FUEL ECONOMY RATIO	RELATIVE RANGE	TRUNK SPACE	ACCEL (0-60), SEC.	TOP SPEED, MPH
CONV.	NA	NA	$18,700	18.7 MPG	350 MILES	NA.	12.1 s.	122 MPH
ADVANCED DIESEL	2003	2008	Intro: 1.2 Mat.: 1.1	Intro: 1.15 Mat.: 1.25	Intro: 1.2 Mat.: 1.2	Intro: 1.0 Mat.: 1.0	13.1 s.	122 mph
NATURAL GAS VEHICLE	1998	2002	Intro: 1.22 Mat.: 1.1	Intro: 1.0 Mat.: 1.0	Intro: 0.75 Mat.: 0.9	Intro: 0.75 Mat.: 0.9	12.1 s.	122 mph
DEDICATED ALCOHOL	2005	2005	Intro: 1.0 Mat.: 1.0	Intro: 1.08 Mat.: 1.08	Intro: 0.9 Mat.: 0.9	Intro: 1.0 Mat.: 1.0	12.1 s.	122 mph

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These are the attribute values for the "Cargo Truck" category. In 1995, cargo trucks accounted for 19.4% of sales. Average characteristics include (1) 293 cubic inch engines; (2) 175.1 HP; and (3) 118.8 inch wheelbase. Davis, Stacy, Transportation Energy Data Book: Edition 16, Oak Ridge National Laboratory, ORNL-6898, July 1996.

Cargo Trucks include pickups and large vans.

Electric vehicles. fuel cell vehicles, and hybrid vehicles are not competing in this market segment.

Vehicle Cost Ratios

TECHNOLOGY	STATUS	SMALL CAR	LARGE CAR	PASSENGER TRUCK	CARGO TRUCK	COMMENTS
ELECTRIC	INTRO.	2.20	NIC	2.00	NIC	1998 SMALL CAR
	MATURITY	1.15	NIC	1.15	NIC	2015 SMALL CAR
ADVANCED	INTRO.	1.10	1.10	1.15	1.20	2003 PASS TRUCK
DIESEL	MATURITY	1.05	1.05	1.10	1.10	2008 PASS TRUCK
HYBRID	INTRO.	1.30	1.30	1.24	NIC	2005 LARGE CAR
	MATURITY	1.20	1.20	1.20	NIC	2015 LARGE CAR
FUEL CELL	INTRO.	NIC	1.40	1.30	NIC	2009 LARGE CAR
	MATURITY	NIC	1.25	1.30	NIC	2013 LARGE CAR
NATURAL	INTRO.	NIC	1.20	1.10	1.20	1998 LARGE CAR
GAS	MATURITY	NIC	1.07	1.10	1.10	2002 LARGE CAR
ETHANOL	INTRO.	1.00	1.00	1.00	1.00	2005
	MATURITY	1.00	1.00	1.00	1.00	2005

Vehicle cost ratio assumptions for the 4 vehicle categories are indicated on this slide.

The table also indicates the vehicle categories in which the individual technologies are not competing (NIC).

Highest cost technologies include: electric, fuel cell and hybrid.

Ethanol-fueled vehicles are consistently shown as the lowest cost technology.

NIC: Stands for "Not in Category."

Relative Range Ratios

TECHNOLOGY	STATUS	SMALL CAR	LARGE CAR	PASSENGER TRUCK	CARGO TRUCK
ELECTRIC	INTRO.	0.50	NIC	0.30	NIC
	MATURITY	0.70	NIC	0.60	NIC
ADVANCED DIESEL	INTRO.	1.20	1.20	1.20	1.20
	MATURITY	1.20	1.20	1.20	1.20
HYBRID	INTRO.	1.00	1.00	1.00	NIC
	MATURITY	1.00	1.00	1.00	NIC
FUEL CELL	INTRO.	NIC	1.00	1.00	NIC
	MATURITY	NIC	1.00	1.00	NIC
NATURAL GAS	INTRO.	NIC	0.66	0.75	0.75
	MATURITY	NIC	0.75	0.75	0.90
ETHANOL	INTRO.	0.90	0.90	0.90	0.90
	MATURITY	0.90	0.90	0.90	0.90

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Vehicle range ratio assumptions for the 4 vehicle categories are indicated on this slide.

The table also indicates the vehicle categories in which the individual technologies are not competing (NIC).

Electric vehicles are shown with significant range penalties. Natural gas-fueled vehicles also are shown as having range penalties

Advanced diesel vehicles are shown as having a range benefit due to the higher volumetric energy content of diesel fuel compared to gasoline.

Fuel Economy Ratios

TECHNOLOGY	STATUS	SMALL CAR	LARGE CAR	PASSENGER TRUCK	CARGO TRUCK
ELECTRIC	INTRO.	3.00	NIC	3.00	NIC
	MATURITY	3.00	NIC	3.00	NIC
ADVANCED DIESEL	INTRO.	1.20	1.30	1.15	1.15
	MATURITY	1.25	1.30	1.25	1.25
HYBRID	INTRO.	1.90	1.75	1.40	NIC
	MATURITY	2.30	2.50	2.10	NIC
FUEL CELL	INTRO.	NIC	2.50	2.50	NIC
	MATURITY	NIC	2.50	2.50	NIC
NATURAL GAS	INTRO.	NIC	1.00	1.00	1.00
	MATURITY	NIC	1.00	1.00	1.00
ETHANOL	INTRO.	1.08	1.08	1.08	1.08
	MATURITY	1.08	1.08	1.08	1.08

Vehicle fuel economy ratio assumptions for the 4 vehicle categories are indicated on this slide.

The table also indicates the vehicle categories in which the individual technologies are not competing (NIC).

Highest performing technologies include: electric, hybrid and fuel cell.

Natural gas-fueled vehicles are consistently shown as the lowest performing technology.

Transportation Energy Prices*

Fuel Type	2000	2010	2020
Gasoline	1.31	1.38	1.34
Diesel	1.22	1.26	1.29
CNG	0.82	0.81	0.96
Electricity	1.91	1.94	1.92
Ethanol	1.80	1.44	1.34

* 1994 $ per 125,000 btu ref: DOE/EIA-0383(96) Annual Energy Outlook 1996
Prices include Federal and State taxes and exclude county and local taxes.
Electricity prices reflect indusrtial/expected off-peak prices
Ethanol prices reflect goals as stated in the 1997 Budget.

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This slide shows fuel prices projected for years 2000, 2010, and 2020.

Ethanol prices reflect goals of the program and DO NOT incorporate any tax incentives.

Biomass Fuel Use

	2000	2010	2020
Direct Biomass Ethanol Use (billion gallons per year)	0.11	5.55	11.77
Blends and Extenders (billion gallons per year)	0.09	6.45	8.23
Supply Constraint (billion gallons)	0.20	12.0	20.0
Fuel Availability (percent of stations)	0.5%	15%	29%

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This slide shows the amount of fuel demanded by flex-fuel, dedicated alcohol and fuel cell vehicles.

Fuel availability is constrained to the above levels given assumptions regarding new plant start-ups.

The split of ethanol use in blends compared to direct use is roughly 50% and based on input from the OTT Office of Fuels Development.

Vehicle Sales Shares

	1994	2000	2010	2020
Small Car	32.1%	33.8%	30%	30%
Large Car	27.5%	24.2%	22%	22%
Passenger Truck	18.2%	20.1%	24%	22%
Cargo Truck	20.9%	22.0%	24%	22%

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This slide indicates projected vehicle sales shares.

As you can see, by 2010 we project that light trucks will account for 48% percent of the light duty market. EIA projects light trucks to max. out at 43%; J.D. Power projects light truck share to rise to 50% then decline; DRI projects light truck share to rise to 48%; Auto Pacific projects light truck share to rise to 47%.

Size Class Market Penetration

Small Car

Large Car

Passenger Truck

Cargo Truck

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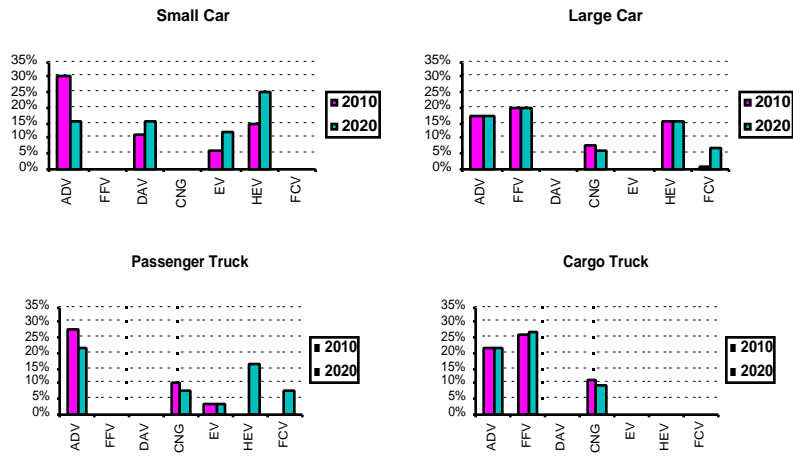
Market Penetration of Alternative Light Vehicles

Technology (LDV)	2000		2010		2020	
	Sales	Stock	Sales	Stock	Sales	Stock
Advanced Diesel	0.0%	0.0%	24.9%	6.6%	18.9%	17.9%
Dedicated ETOH	0.0%	0.0%	3.4%	0.9%	4.7%	3.4%
Alcohol Flex	5.1%	0.6%	10.6%	8.2%	18.9%	9.9%
CNG	1.7%	0.2%	6.9%	4.2%	5.5%	5.7%
Hybrid	0.0%	0.0%	8.0%	1.4%	14.8%	11.0%
Electric	0.8%	0.1%	2.7%	2.0%	4.3%	3.6%
Fuel Cell	0.0%	0.0%	0.2%	0.0%	3.3%	1.8%
Total	7.6%	0.9%	56.7%	23.3%	62.4%	53.4%

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This slide details the sales and stocks of advanced light duty vehicle technologies in years 2000, 2010,and 2020.

The light duty vehicle sales penetration estimates are a weighted average of the sales penetration estimates made by size class.

The analyses show that at aggressive market penetration rates, it takes approximately 20 years for advanced technologies to comprise about 60% of the stock of light duty vehicles in use.

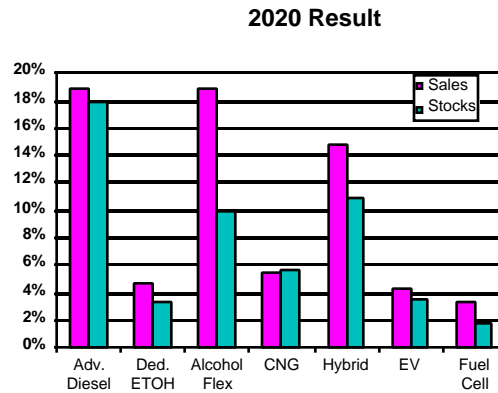# Penetration of Alternative in Light Vehicles
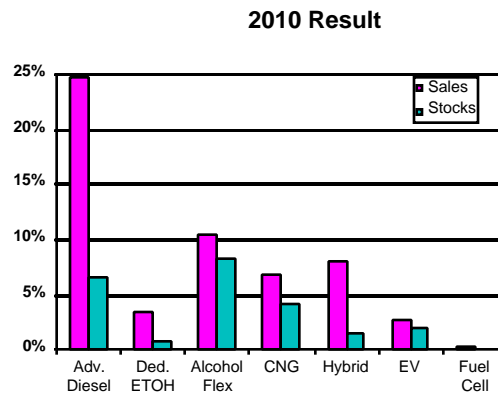
2010 Result

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This slide is a graphical representation of the sales and stocks of light duty vehicles in year 2010.

Sales are a percent of overall sales in 2010. Stocks are percent of cumulative stock of vehicles in 2010.

Penetration of Alternative in Light Vehicles

2020 Result

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This slide is a graphical representation of the sales and stocks of light duty vehicles in year 2020.

Sales are a percent of overall sales in 2020. Stocks are percent of cumulative stock of vehicles in 2020.

Technology Characteristics Comparison - Year of Maturity

TECHNOLOGY		YEAR OF MATUR-ITY	VEHICLE COST RATIO	FUEL ECON. RATIO	RANGE RATIO	EMIS-SIONS (TAIL PIPE)	TYPE OF FUEL
ELECTRIC	QM-98	2015	1.15	3	0.7	0	NON-PETRO.
(Note: QM 98	QM-97	2003	1.1	5.2	0.67	0	NON-PETRO.
small cars)	QM-95	2005	1.1	3.7	0.5	0	NON-PETRO.
ADVANCED	QM-98	2012	1.05	1.3	1.2	TIER II	D.F. NO. 2
DIESEL	QM-97	2005	1.02	1.35	1	TIER II	D.F. NO.2
	QM-95	n/a	n/a	n/a	n/a	n/a	n/a
HYBRID	QM-98	2015	1.2	2.5	1	TIER II	GASOLINE
(PNGV)	QM-97	2015	1.07	3	1	TIER II	ANY
	QM-95	n/a	n/a	n/a	n/a	n/a	n/a
FUEL CELL	QM-98	2013	1.25	2.5	1	0.1XCONV	ETOH/HYDR.
	QM-97	2012	1.1	3	1	ULEV	MEOH/ETOH
	QM-95	2017	1.1	3.2	1		ANY
NATURAL	QM-98	2002	1.07	1	0.75	ULEV	NAT. GAS
GAS	QM-97	2003	1.05	1	0.9	TIER II	NAT. GAS
	QM-95	2003	1	1	0.9		NAT. GAS
LPG	QM-98	NOT INCLUDED					
	QM-97	2003	1	1	1	TIER II	PROPANE
	QM-95	n/a	n/a	n/a	n/a	n/a	n/a
ETHANOL-	QM-98	2005	1	1.08	1	ULEV	ETHANOL
FUELED	QM-97	2010	1	1.15	0.9	TIER II	ETHANOL
	QM-95	n/a	n/a	n/a	n/a	n/a	n/a
LIGHT WEIGHT	QM-98	NOT INCLUDED					
(ALUMINUM)	QM-97	2010	1.03	1.21	1	TIER II	GASOLINE
	QM-95	2015	1	n/a	1		GASOLINE

NOTE: MATURITY IS DEFINED AS THE TIME AT WHICH "ZERO GOV. FUNDING" OCCURS.

2/6/07

This is the third round of "Quality Metrics". As a result, it is the third time we have completed a vehicle characterization exercise.

For previous QM efforts, we used a generic light vehicle that corresponded to a large car.

A few observation are: the years of maturity have remained rather consistent, except for electric vehicles.

"Mature" cost ratios have increased for the most recent estimates

Fuel economy ratio inputs have been consistent, except for electric vehicles which have shown rather significant variation.

Market Penetration Forecast Comparisons
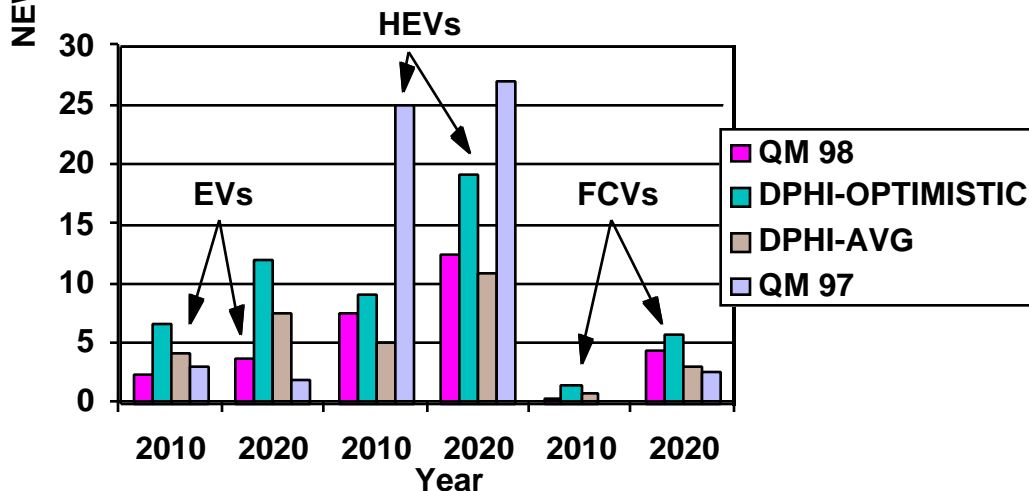
Note: Delphi Values from Ng, et. al (SAE 8/95)
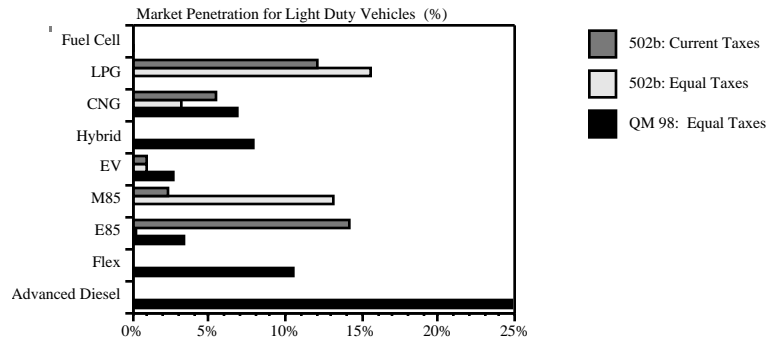
2/6/97

This chart compares the market penetration (percentage of new car sales) estimates from four sources: QM 98, Delphi survey- optimistic responses, Delphi survey- average responses, and QM 97.

Technologies indicated are electric, hybrid, and fuel cell vehicles for the years 2010 and 2020.

The comparisons are interesting, but not consistent. Delphi respondents are more optimistic about electric vehicles than either Quality Metrics analysis indicated. Conversely, OTT program expectations are more optimistic than the Delphi respondents relative to hybrid vehicles. Anticipated market penetration of fuel cell vehicles is consistently low, with the optimistic Delphi estimate of more than 5% in the year 2020 being the highest projection.

Source: Henry Ng et. al., The Prospects for Electric and Hybrid Electric Vehicles: Second-Stage Results of a Two-Stage Delphi Study, SAE Technical Paper Series 961698, August 1995.

Comparison of QM 98 and two 502(b) Scenarios in 2010

Market Penetration for Light Duty Vehicles (%)

- Fuel Cell
- LPG
- CNG
- Hybrid
- EV
- M85
- E85
- Flex
- Advanced Diesel

0%   5%   10%   15%   20%   25%

- 502b: Current Taxes
- 502b: Equal Taxes
- QM 98: Equal Taxes

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This slide shows a comparison of market penetration results. It includes QM98 results and last year's QM results, as well as two scenarios from the 502(b) study.

We choose the current tax and equal tax scenarios from the 502(b) study. These two scenarios show that tax assumptions have a large impact on methanol and ethanol vehicle market penetration.

We have taken the equal tax approach in the quality metrics exercise.

Electric Vehicle Offline Fleet Market Penetration Assumptions

	Year (Sales in thousands)				
	2000	2005	2010	2015	2020
ZEV Mandates	15	135	252	262	275
Fuel Providers	4.8	5	6.1	6	6.1
Station Cars	2.5	3	3	10.5	18
Total	22	143	261	279	299

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Another refinement of QM 98 is to specifically address fleets, and baseline alternative fuel vehicles in the market place, absent any effects of the OTT R&D program.

Assumptions relating to EV sales are shown here. ZEV mandated vehicles dominate the market penetration effects. EPAct-based purchases of EVs by fuel providers also is included, as is the category of "Station Vehicles"- which can be considered as a place holder for specialized duty cycle uses of EVs.

Note: slide represents 1000's of vehicles

QM 98 Oil Impacts from Off-line Electric Vehicle Calculations and EIA Baseline Alternative Fuel Use (Quads)

	2000	2005	2010	2020
Electric Vehicles	0.000	0.001	0.006	0.013
Methanol	0.000	0.002	0.002	0.003
Ethanol	0.000	0.000	0.000	0.000
Natural Gas (CNG)	0.052	0.159	0.166	0.152
Propane (LPG)	0.025	0.087	0.106	0.096

The QM oil benefits of mandated and other fleet-type applications of electric vehicles and estimated fleet alternative fuel use from EIA are summarized in this table.

For electric vehicles, the sales assumptions indicated above result in approximately 1,500,000 vehicles in use in 2010, and just over 3,000,000 vehicles in 2020.

- Payback Model
  - Energy Cost Savings vs. Capital Cost
- Assumed Payback Period: 2, 3, or 4 years
- Distribution of Payback Periods: 60% 2 year, 35% 3 year, 5% 4 year
- Discount Rate: 10%
- Rate of Technology Adoption
- Four Market Classes

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This slide describes the structure of the Heavy Duty Market Penetration Model. The model is a spreadsheet model that calculates whether energy efficiency or fuel savings associated with advanced truck engines are profitable to truck users/owners.

Trucks users/owners are placed in different Payback categories of 2, 3, or 4 years. These shares are based on phone interviews with truck sellers.

The model estimates fuel savings to truckers based on miles driven, fuel economy, and fuel prices; then compares the savings to incremental cost of new technology. A discount rate of 10% is used. In order for the model to project sales, the energy savings must payback within 2, 3, or 4 years, depending on the payback required by the trucking sector.

In order to generate an S-curve to the penetration estimates, a variable called "rate of technology adoption." This variable is based on historical data.

The model has a different spreadsheet for four different truck markets which are described on the next slide.

Heavy Vehicle Market Classes

- Medium: Centrally Refueled [35% of class 3 to 6 vehicles]
- Medium: Non-Centrally Refueled [65% of class 3 to 6 vehicles]
- Heavy: Over 50k Miles Per Year [42% of class 7 and 8 vehicles]
- Heavy: Under 50k Miles Per Year [58% 0f class 7 and 8 vehicles]

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The model is divided into four market classes: two for medium trucks and two for heavy trucks. Medium trucks are trucks in classes 3 to 6. Heavy trucks are trucks in classes 7 and 8.

Medium trucks are split into centrally refueled trucks and non-centrally refueled trucks. This was done because the two groups are driven differently and because alternative fuels probably have a better chance of penetrating the centrally refueled fleet.

Heavy trucks are divided into two classes also. Trucks that drive over 50k miles a year and trucks that drive less than 50k a year. This is a good way of separating the over the road trucks from other class 7 and 8 trucks such as dump trucks and cement mixers. These two types of trucks are VERY DIFFERENT in terms of use and fuel economy.

Heavy Vehicle Characteristics by Class

	Percent of Vehicles	Percent of Fuel Use	Average Annual Miles	Average Base Fuel Economy (mpg)
Medium: Centrally Refueled	20.2%	8.9%	14,450	7.9
Medium: Non-Centrally Refueled	37.3%	13.1%	10,879	7.5
Heavy: Over 50k Miles	18.0%	56.0%	95,433	7.4
Heavy: Under 50k Miles	24.5%	22.0%	15,155	4.1

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This slide shows key demographics for the four trucks markets such as percent of trucks in each market class; fuel use by market class; average annual miles; and fuel economy.

Notice the dramatic and surprising difference in fuel economy for class 7 and 8 trucks.

OTT has modeled high efficiency, natural gas engine penetration in medium trucks and heavy trucks that travel less than 50k miles. OTT has modeled advanced diesel engine penetration in heavy trucks that travel over 50k miles annually only.

Source: ORNL manipulation of the TIUS database.

Medium--Centrally Refueled: Natural Gas Vehicle

	2000	2005	2010	2015	2020
Incremental Cost ($1994)	NA	$6,000	$4,000	$4,000	$4,000
Base Fuel Economy (mpg)	7.93 mpg	7.96 mpg	7.98 mpg	8.01 mpg	8.04 mpg
Fuel Economy (mpg)	NA	9.15 mpg	9.18 mpg	9.21 mpg	9.25 mpg
Diesel Cost ($ per gallon)	$1.19	$1.22	$1.22	$1.24	$1.28
Natural Gas Cost ($ per gde)	$0.88	$0.88	$0.87	$0.96	$1.01

This slide shows the model input, at five year intervals, for the natural gas truck in the medium centrally-refueled market.

Truck availability begins in 2005--five years after the introduction of the advanced diesel engine in class 7 and 8 trucks.

Fuel economy is about 15% higher than the conventional competitor.

Incremental vehicle costs are aggressive.

Medium--Non-Centrally Refueled: Natural Gas Vehicle

	2000	2005	2010	2015	2020
Incremental Cost ($1994)	NA	$6,000	$4,000	$4,000	$4,000
Base Fuel Economy (mpg)	7.53 mpg	7.55 mpg	7.58 mpg	7.61 mpg	7.63 mpg
Fuel Economy (mpg)	NA	8.68 mpg	8.72 mpg	8.75 mpg	8.77 mpg
Diesel Cost ($ per gallon)	$1.19	$1.22	$1.22	$1.24	$1.28
Natural Gas Cost ($ per gde)	$0.88	$0.88	$0.87	$0.96	$1.01

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This slide shows the model input, at five year intervals, for the natural gas truck in the medium non-centrally refueled market.

Truck availability begins in 2005--five years after the introduction of the advanced diesel engine in class 7 and 8 trucks.

Fuel economy is about 15% higher than the conventional competitor.

Incremental vehicle costs are aggressive.

Heavy: Natural Gas Vehicle

	2000	2005	2010	2015	2020
Incremental Cost ($1994)	NA	$9,000	$9,000	$8,000	$7,000
Base Fuel Economy (mpg)	4.25 mpg	4.40 mpg	4.55 mpg	4.71 mpg	4.88 mpg
Fuel Economy (mpg)	NA	5.28 mpg	5.91 mpg	6.12 mpg	6.34 mpg
Diesel Cost ($ per gallon)	$1.19	$1.22	$1.22	$1.24	$1.28
Natural Gas Cost ($ per gde)	$0.88	$0.88	$0.87	$0.96	$1.01

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This slide shows the model input, at five year intervals, for the natural gas truck in the heavy under 50k miles market..

Truck availability begins in 2005--five years after the introduction of the advanced diesel engine in class 7 and 8 trucks.

Fuel economy is about 15% higher than the conventional competitor.

Incremental vehicle costs are $1000 greater than the advanced diesel engine competing in the heavy over 50k miles market.

Heavy: Advanced Diesel Vehicle

	2000	2005	2010	2015	2020
Incremental Cost ($1994)	$8,000	$8,000	$8,000	$7,000	$6,000
Base Fuel Economy (mpg)	7.66 mpg	7.93 mpg	8.22 mpg	8.51 mpg	8.81 mpg
Fuel Economy (mpg)	9.19 mpg	10.31 mpg	10.69 mpg	11.06 mpg	11.45 mpg
Diesel Cost ($ per gallon)	$1.19	$1.22	$1.22	$1.24	$1.28

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This slide shows the model input, at five year intervals, for the advanced diesel engine competing in the heavy over 50k miles market.

Truck availability begins in 2000.

Fuel economy is about 30% higher than the conventional competitor.

Heavy Vehicle Market
Penetration Results

	2000	2005	2010	2015	2020
Medium NGV: Centrally Refueled	0.0%	0.0%	0.2%	1.1%	3.4%
Medium NGV: Non-Centrally Refueled	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy Advanced Diesel: Over 50k Miles	0.7%	7.2%	24%	38%	45%
Heavy NGV: Under 50k Miles	0.0%	0.0%	0.0%	0.0%	0.0%

This slide illustrates market penetration numbers given our assumptions.

The heavy over 50k miles market is the only market that advanced engines do well in. That is because this market values fuel economy greatly due to the amount of miles the trucks travel annually. The fact that conventional engines are already very fuel efficient, makes it tougher for the advanced diesel to compete.

The natural gas trucks don't do very well. That is because that in the markets in which they compete, trucks are not driven enough or expected Payback periods are very short. To increase penetration, in the model, incremental cost would need to be lower. Yet, these costs are also very low. Increasing the assumption of fuel economy gain would also help.

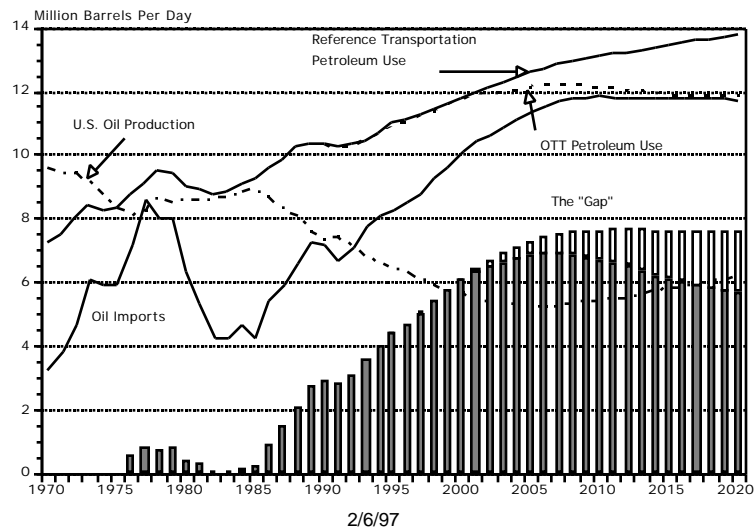# Off-line Heavy Truck Lightweight Materials Savings

- Reducing truck weight will allow trucks to carry more weight--38% of trucks "weight-out" according to TIUS.
- Two levels of weight reduction are planned:
  - » 2000 pounds in 2003
  - » 5000 pounds in 2008
- Fuel savings on an individual truck basis are:
  - » 3.3% for 2000 pound weight reduction (2,000/60,000)
  - » 8.3% for 5000 pound weight reduction (5,000/60,000)
- Stock penetrations:
  - » for 2000 pound weight reduction are 20% in 2010 and 20% in 2020
  - » for 5000 pound weight reduction are 6% in 2010 and 63% in 2020
- Fuel savings (percent of trucks that weight-out x stock penetration x fuel savings) for class 7/8 market are:
  - » 0.44% in 2010 (0.03 quads maximum)
  - » 2.24% in 2020 (0.17 quads maximum)

Estimated Impacts

- Energy Use: Reductions in Primary Energy and Oil Use
- Emissions: Criteria and Greenhouse Gas
- Economic: GDP and Jobs

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This slide presents the benefits that will be discussed.

OTT Petroleum Use, the "Gap," and Turning the Corner

Million Barrels Per Day

Reference Transportation Petroleum Use

U.S. Oil Production

OTT Petroleum Use

The "Gap"

Oil Imports

14

12

10

8

6

4

2

0

1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

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Energy Displaced

Technology	Primary Energy Displaced (mmb/d)			Primary Oil Displaced (mmb/d)		
	2000	2010	2020	2000	2010	2020
Technology Utilization	0.00	0.00	0.00	0.05	0.42	0.45
Biofuels	0.01	0.36	0.65	0.01	0.36	0.65
Total Advanced Auto Tech	0.00	0.09	0.55	0.01	0.19	0.73
Light Duty Engine R&D	0.00	0.03	0.11	0.00	0.03	0.11
Electric Vehicle R&D	0.00	0.00	0.00	0.01	0.11	0.18
Hybrid Vehicle R&D	0.00	0.05	0.37	0.00	0.05	0.37
Fuel Cell R&D	0.00	0.00	0.11	0.00	0.00	0.08
Heavy Vehicle R&D	0.00	0.09	0.22	0.00	0.09	0.22
Classes 1 & 2	0.00	0.07	0.12	0.00	0.06	0.12
Classes 3 - 8	0.00	0.02	0.10	0.00	0.03	0.10
Advanced Materials	0.00	0.00	0.02	0.00	0.01	0.04
Total	0.01	0.54	1.44	0.07	1.07	2.08
Baseline	12.15	13.74	14.76	11.49	12.95	14.31
Percent Reduction	0.0%	3.9%	9.8%	0.6%	8.3%	14.5%

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This slide details the energy impacts estimated by technology type.

Carbon Emission Reductions

	Carbon Reductions (MMTons)		
Technology	2000	2010	2020
Technology Utilization	0.56	4.36	4.69
Biofuels	0.23	14.51	25.99
Advanced Automotive Technologies	-0.10	2.73	20.98
Light Duty Engine R&D	0.00	1.26	4.03
Electric Vehicle R&D	-0.10	-0.68	-1.17
Hybrid Vehicle R&D	0.00	2.12	15.19
Fuel Cell R&D	0.00	0.04	2.94
Heavy Vehicle R&D	0.01	3.39	8.46
Classes 1 & 2	0.00	2.36	4.37
Classes 3 - 8	0.01	1.03	4.09
Advanced Materials	0.00	0.00	0.65
Total	0.69	25.00	60.77
Baseline	491.8	552.4	591.0
Percent Reduction	0.1%	4.5%	10.3%

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This slide details carbon emission reductions estimated by technology type.

The slide illustrates carbon savings only--not carbon dioxide or all greenhouse gases.

Economic Spreadsheet Model

- Simple and transparent spreadsheet model
- Model tracks cash flows related to penetration of advanced technologies
- Flows include:
    - » Incremental vehicle costs
    - » Changes in "baseline" consumer spending
    - » Energy savings
    - » Alternative fuel costs
- Cash flows are multiplied by job and GDP multipliers
- Multipliers are derived from a 1985 Department of Commerce data that was benchmarked to 1990 by the ACEEE

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This slide describes the structure of the Economic Spreadsheet Model. As the title implies the model is based on a spreadsheet. The strengths of the model are its simplicity and transparency.

The model tracks changes in cash flows due to the introduction of advanced transportation technologies and estimates job and GDP outcomes.

Flows include incremental costs of new vehicles and the accompanying decline in consumer spending on other items; energy savings; alternative fuel costs; and decreased spending on petroleum products.

Job and GDP multipliers (coefficients) are used to estimate impacts.

Multipliers are derived from Department of Commerce data by the ACEEE. These multipliers are static and historic. The primary criticism of using this approach is that we are applying past data to future impacts. To do otherwise though, would be very complex (i.e.., expensive) and just as speculative.

ESM: Job and GDP Multipliers

	Job Multipliers (Jobs per $M)	GDP Multipliers ($M GPD per $M)
Agriculture	26.86	2.12
Refining	7.14	2.02
Oil and Gas Extraction	7.02	1.34
Gas Utility	7.41	1.99
Electric Utility	9.54	1.78
Motor Vehicles	13.70	2.19
Household	16.80	1.47
Wholesale Trade	20.43	1.47

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This is a list of multipliers used in the model. The multipliers are industry specific at an aggregate level. The multipliers are not correlated to each other because they take into account different economic factors (such as capital-intensity and imports/exports).

Advanced transportation technologies create jobs, in large part, because they induce spending in areas with larger multipliers than areas where the spending was previously done.

For example, by shifting spending from gasoline spending to consumer spending through energy savings results in spending that is over twice as job intensive (16.8 divided by 7.14).

Employment Impacts by Sector of Economy

	2010	*2020*
Motor Vehicles	272,794	386,340
Agriculture	35,547	77,304
Oil/Refining	-124,189	-262,177
Gas Utility	29,840	39,892
Electric Utility	25,265	40,301
"Household"	-169,690	-44,082
Total	*69,567*	*237,578*

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This slide shows a summary of preliminary job impacts by the sector of the economy. It shows that the oil industry loses jobs while most other sector gain jobs.

In 2010, the "household" sector loses jobs primarily because households are paying more for vehicles in that year than they are saving in energy savings (since it is early in many technologies' commercial life and stocks of vehicles haven't had the chance to accumulate).

Illustrative Example: Jobs Calculation for Electric Vehicles in 2010

- Step 1: Effects of Higher Purchase Price of Vehicle. Multiply incremental cost by coefficient for motor vehicle industry. $3136 M x 13.70 Job/$M = 42963 Jobs.
- Step 2: Effects of Reduced Consumer Spending Due to Step 1. Multiply incremental cost by coefficient for household spending. -$3136 M x 16.80 Jobs/$M = -52685 Jobs.
- Step 3: Effects of Reduced Spending on Gasoline. Multiply money that would have been spent on gasoline by coefficient for oil industry (combination of extraction and refining). -$4064 M x 7.06 Jobs/$M = -28702 Jobs.
- Step 4: Effects of Increased Spending on Electricity. Multiply money spent on electricity by coefficient for electric utilities. $2648 M x 9.54 Jobs/$M = 25265 Jobs.
- Step 5: Effects of Energy Cost Savings. Multiply money saved on energy costs by coefficient for household spending. $1416 M x 16.80 Jobs/$M = 23789 Jobs.
- Step 6: Sum Results of Steps 1 to 5 for Net Jobs. 42963 + -52685 + -28702 + 25265 + 23789 = 10630 Net New Jobs.

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This slide walks us through the jobs calculation for electric vehicles in 2010.

Illustrative Example: Jobs Calculation for Heavy Vehicles in 2010

- Step 1: Effects of Higher Purchase Price of Vehicle. Multiply incremental cost by coefficient for motor vehicle industry. $383 M x 13.70 Job/$M = 5247 Jobs.
- Step 2: Effects of Reduced Consumer Spending Due to Step 1. Multiply incremental cost by coefficient for wholesale spending. -$383 M x 20.43 Jobs/$M = -7825 Jobs.
- Step 3: Effects of Reduced Spending on Diesel. Multiply money that would have been spent on diesel by coefficient for oil industry (combination of extraction and refining). -$499 M x 7.06 Jobs/$M = -3524 Jobs.
- Step 4: Effects of Increased Spending on Natural Gas. Multiply money spent on natural gas by coefficient for natural gas utilities. $3 M x 7.41 Jobs/$M = 22 Jobs.
- Step 5: Effects of Energy Cost Savings. Multiply money saved on energy costs by coefficient for wholesale spending. $496 M x 20.43 Jobs/$M = 10133 Jobs.
- Step 6: Sum Results of Steps 1 to 5 for Net Jobs. 5247 + -7825 + -3524 +22 + 10133 = 4053 Net New Jobs.

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This slide walks us through the jobs calculation for heavy vehicles in 2010.

Economic Impacts

Technology	Net New Jobs (thousands)			Net Increase in GDP ($ millions)		
	2000	2010	2020	2000	2010	2020
Technology Utilization	1.3	32.9	29.0	$54	$1,798	$3,935
Biofuels	0.5	27.8	74.8	$726	$3,207	$3,615
Total Advanced Auto Tech	(6.4)	2.2	88.6	$1,427	$7,763	$13,304
Light Duty Engine R&D	0.00	4.0	21.6	$0	$726	$601
Electric Vehicle R&D	(6.4)	10.6	26.5	$1,427	$2,404	$2,343
Hybrid Vehicle R&D	0.00	(11.3)	43.3	$0	$4,400	$7,637
Fuel Cell R&D	0.00	(1.1)	(2.8)	$0	$233	$2,723
Heavy Vehicle R&D	0.00	(11.5)	34.9	$0	$4,236	$14,428
Classes 1 & 2	0.00	(0.2)	13.0	$0	$726	$601
Classes 3 - 8	0.00	(11.3)	21.9	$0	$3,510	$13,827
Advanced Materials	NA	NA	NA	NA	NA	0.04
Total	(4.6)	69.6	237.6	$2,241	$19,428	$38,277
Baseline	120,400	133,500	148,000	$6126k	$7485k	$9145k
Percent Reduction	0.0%	0.1%	0.2%	0.04%	0.26%	0.42%

This slide provides a summary of the model's output.

Baseline numbers are at the bottom of the table. They show that while the economic impacts are large in absolute numbers, they are small compared to the baseline--less than 1%.

The analysis implicitly assumes less than full

Benefit-Cost Cumulative Table
($ Millions)

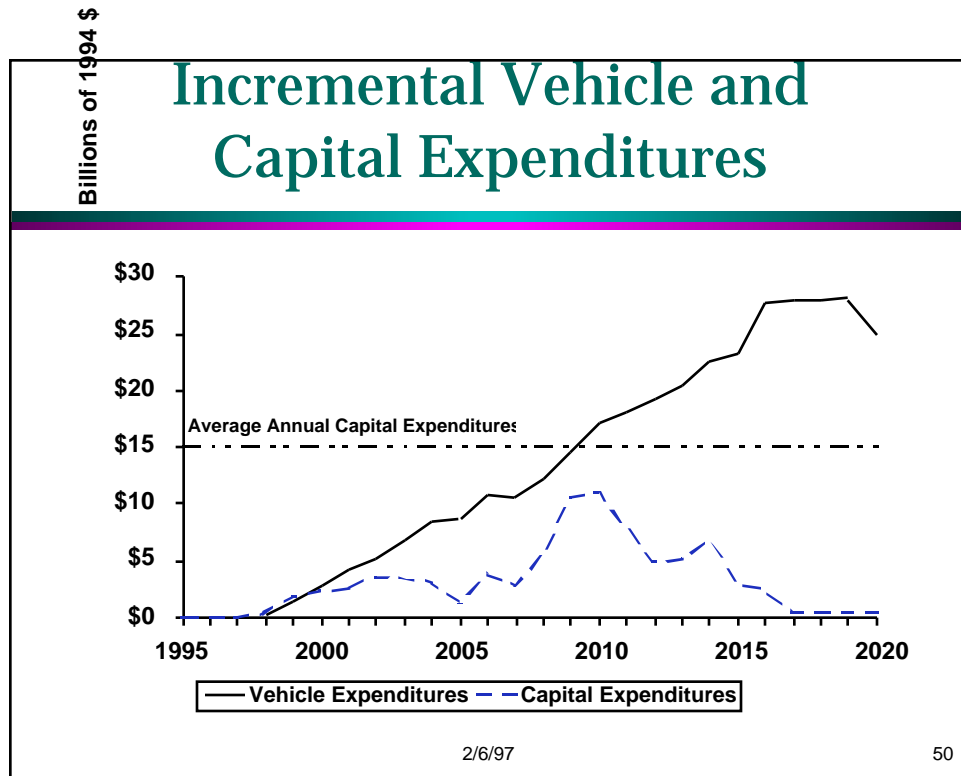|	2000	2005	2010	2015	2020
Costs					
Budget Costs	$600	$1,600	$2,000	$2,000	$2,000
Total	$600	$1,600	$2,000	$2,000	$2,000
Benefits					
Energy Savings	$264	$5,373	$31,472	$98,297	$202,856
Oil Security ($4 per bbl)	$13	$312	$1,178	$2,533	$4,216
Gasoline Price Decline	$2,519	$6,912	$11,460	$16,061	$20,671
Distillate Price Decline	$511	$1,420	$2,381	$3,379	$4,408
Residual Price Decline	$264	$743	$1,270	$1,843	$2,458
Natural Gas Price Rise	($1,754)	($4,788)	($7,955)	($11,238)	($14,628)
CO2 ($15 per ton)	$21	$754	$3,944	$12,008	$24,858
NOX ($2,750 per ton)	$4	$226	$1,538	$4,571	$9,072
CO ($300 per ton)	$13	$477	$3,090	$10,250	$21,167
HC ($3,050 per ton)	$18	$487	$2,636	$7,967	$15,298
Incremental Costs	($5,208)	($46,429)	($122,398)	($241,220)	($377,840)
GDP Benefits	$2,745	$39,139	$120,330	$251,663	$436,701
Total	($589)	$4,627	$48,945	$156,114	$349,237
Benefit-Cost Ratio	-0.98	2.89	24.47	78.06	174.62

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This slide provides a summary of all costs and benefits associated with OTT's QM98 estimates in cumulative terms.

Costs include incremental vehicle costs; DOE budgets; and the induced increase in natural gas prices.

Benefits include energy savings; oil security benefits; induced price declines in petroleum products; decreased emissions of greenhouse gases and ambient pollutants; and increased GDP.

A benefits-cost ratio is shown at the bottom. The numbers do not take discounting into consideration.

Incremental Vehicle and Capital Expenditures

Billions of 1994 $

Average Annual Capital Expenditures

Vehicle Expenditures — — Capital Expenditures

2/6/97   50

This slide is a graphical representation of the costs and benefits associated with the successful introduction of advanced technologies in the light duty vehicle market from the manufacturer's perspective. Comparing total vehicle expenditures to capital cost requirements, it is shown that advanced technologies generate significantly more revenues than capital expenditures.

Capital cost investment numbers are based on building production facilities. We estimated the following costs:

Advanced diesel vehicles and heavy trucks: $300 million per 100,000 vehicles;

CNG vehicles: $700 million per 100,000 vehicles;

EV, HEV, and FCV: $2 billion per 100,000 vehicles.

Costs are based on literature searches for current expenditures-- advanced diesel costs are based on cost of a new engine facility; CNG vehicle costs are based on costs of major upgrades for conventional vehicles; and electromotive technology costs are based on costs for totally redesigned models.